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SAVANT-LIKE SKILLS EXPOSED IN NORMAL PEOPLE BY SUPPRESSING THE LEFT FRONTO-TEMPORAL LOBE

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The astonishing skills of savants have been suggested to be latent in everyone, but are not normally accessible without a rare form of brain impairment. We attempted to simulate such brain impairment in healthy people by directing low-frequency magnetic pulses into the left fronto-temporal lobe. Significant stylistic changes in drawing were facilitated by the magnetic pulses in 4 of our 11 participants. Some of these 'facilitated' participants also displayed enhanced proofreading ability. Our conclusions are derived from eleven right-handed male university students, eight of whom underwent placebo stimulation. We examined performance before, during and after exposure to the stimulation.

Keywords: nonconscious skills, autistic savants, savants, TMS, drawing, creativity, fronto-temporal lobe, nonconscious processing, consciousness, autism, transcranial magnetic stimulation, neural inhibition, neural disinhibition, brain impairment, rTMS.

1. Introduction

Savants(5,21,22) are rare individuals who, although severely brain impaired, display islands of astonishing excellence in specific areas including drawing, memory, music, calendar calculations, and arithmetic. They typically have no idea how they do it.

One view is that savants acquire their peculiar skills like any normal person, through repetitive practice(7). Another view is that savants have more highly developed brains in specific domains(13,15). These explanations do not fit well with reports that savant skills can emerge 'spontaneously', e.g. following an accident(10,22) or at the onset of fronto-temporal dementia(11), and that these skills do not improve qualitatively with time, even though they may become better articulated(13). Furthermore, it would appear highly coincidental that a single savant can display several of these peculiar skills and that the same skills are so compelling to savants across cultures(16,22).

An alternative explanation is that savant skills are largely innate, requiring little or no practice. Because of their brain impairment, savants have a paradoxical facilitation of information that resides equally within everyone but cannot normally be accessed(20,21).

To test this hypothesis, Snyder suggested(2) that repetitive transcranial magnetic stimulation (rTMS) may be used to temporarily facilitate savant-like skills in normal people. Low frequency (rTMS) inhibits brain activity thereby creating 'virtual lesions'(6,14). Accordingly, we delivered rTMS for 15 minutes at either 0.5 Hertz (nine participants) or 1 Hertz (two participants) over the left fronto-temporal lobe of 11 healthy participants. This site is known to be implicated in the savant syndrome both for a young artistic savant and savants who emerge late in life due to fronto-temporal lobe dementia(11).

2. Methods

2.1. Participants

Eleven right-handed male volunteers, who were unaware of the detailed hypothesis being investigated and who had not previously participated in studies using transcranial magnetic stimulation, were recruited from local university students. The study was approved by the human ethics committees at the University of Sydney and the University of New South Wales. All participants gave written consent for the stimulation procedures. Participants were screened according to guidelines outlined in Wasserman(23) and the Transcranial Magnetic Stimulation Adult Safety Screen produced by Keel(9).

Participants were required to attend two experimental sessions which were separated by approximately one week. Four of the participants received placebo stimulation on week one and real stimulation on week two; the remaining seven received real stimulation on week one and (4 of the 7) placebo stimulation on week two. The order in which placebo and real stimulation were administered for each participant was randomly generated.

2.2. Stimulation protocol

Repetitive transcranial magnetic stimulation (rTMS) was administered using two MagStim 200 magnetic stimulators linked by a bi-stim unit (MagStim Co., Wales, U.K.) with a 70mm figure-of-eight coil. The resting motor threshold (MT) was determined by placing the coil over the left primary motor area and establishing the minimum amount of stimulator output required to produce a motor evoked potential with a peak-to-peak amplitude of $\geq 50\mu V$ in the right first dorsal interosseous muscle following at least three out of five single pulses.

The left anterior-temporal cortical stimulation site was determined by measuring laterally and anteriorly from the vertex (laterally 40% of the interauricular distance, anteriorly 5% of the distance from inion to naison). This point lies approximately halfway between T3 and F7 on the international10-20 system for electrode placement. Stimulation was applied to this region with the handle of the coil held vertically upwards. In the real stimulation condition, the intensity of stimulation was 90% MT. In the placebo condition, the stimulus intensity was applied at 10% maximum stimulator output. To ensure a control, the participants were informed that we were testing two different types of stimulation.

Stimulation was applied for 15 minutes at a frequency of 0.5Hz (9 participants) or 1Hz (2 participants). Eight of the participants who received 0.5Hz stimulation also underwent placebo stimulation either the week before or after the real test in a random, single-blind cross-over design.

3. Effects Of RTMS On Participant Performance

Participants were required to complete a series of four tasks during the course of the experiment. The tasks included drawing and proofreading. Participant performance on each of the tasks was evaluated before, during, immediately after and 45 minutes after 15 minutes of real and placebo magnetic stimulation.

Participants were allowed to practice each task before TMS testing commenced. The order of the tasks was randomised for each participant, but individual participants received the tasks in the same order in their real and placebo stimulation sessions. The four-task set took 5-6 minutes to complete and participants' verbal reports were recorded.

3.1. Drawing

The participants completed two tasks that involved drawing. In one task, they were given one minute to draw either a dog or a horse. This was a random choice. One week later, during their second session, they were then instructed to draw the other animal.

In the second drawing task, the participant was shown an image of a female face on a computer screen placed in front of them for 30 seconds. At the end of the 30 seconds the image was removed from the screen and the participant was allowed one minute to reproduce/draw the image. The image used was randomly chosen from nine images and, excluding the practice drawing, **the participant did not draw the same image more than once**.

In order to ensure objectivity, a committee first inspected all of the drawings (arranged in random order) to judge them for the "best" art. This did **not** lead to any consensus. In other words, magnetic stimulation did not lead to a systematic improvement in naturalistic drawing ability. However, a subsequent committee was asked to judge whether drawings (including those under placebo) within any series showed a demonstrable change of scheme or convention. This led unambiguously to the sets we present here. Ratings by raters who are blind to the order of the drawings is a standard method of psychological evaluation.

Magnetic stimulation caused a major change in the schema or convention of the drawings of four participants. One of these participants received 1Hz stimulation, the other three received 0.5Hz stimulation. Two of these also underwent placebo stimulation either the week before or after the real test. We emphasise that changes in drawing style were observed *only* following real stimulation and not after placebo stimulation.

After 10 minutes of stimulation, participants N.R. and A.J. (figure 1) radically changed their schema for dogs from their initial two drawings before stimulation. The drawings completed before the stimulation were typical caricatures of an animal standing up and facing to the left. During and after stimulation, the style dramatically changed, with the drawings becoming more complex. Participants N.R. and A.J. were unable to return for placebo stimulation.

The horses of D.C. changed their direction becoming more life-like, even flamboyant (figure 2), compared to the drawing he completed before stimulation. D.C. attended a placebo stimulation session the week later, and no style change was observed.

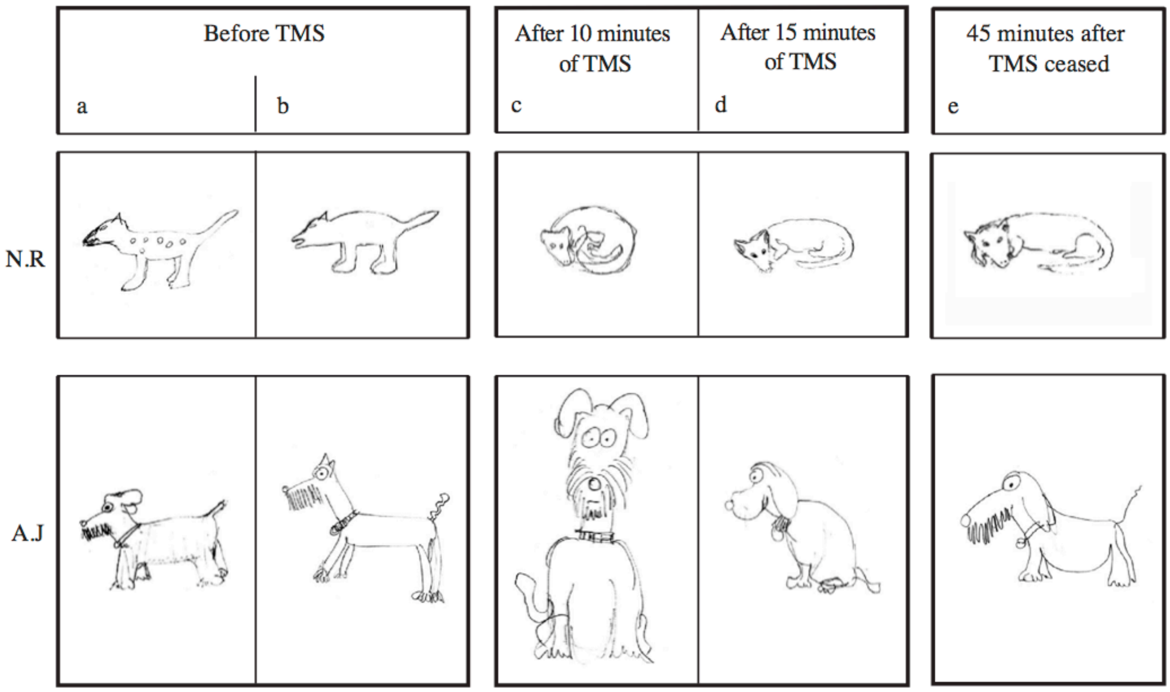


Figure 1. Effect of transcranial magnetic stimulation (TMS) on drawing ability in two participants. The figure illustrates a dog drawn from memory by participants N.R. and A.J. a, b, practice session before the application of TMS; c, during TMS; d, immediately after TMS and e, 45 minutes after TMS ceased.

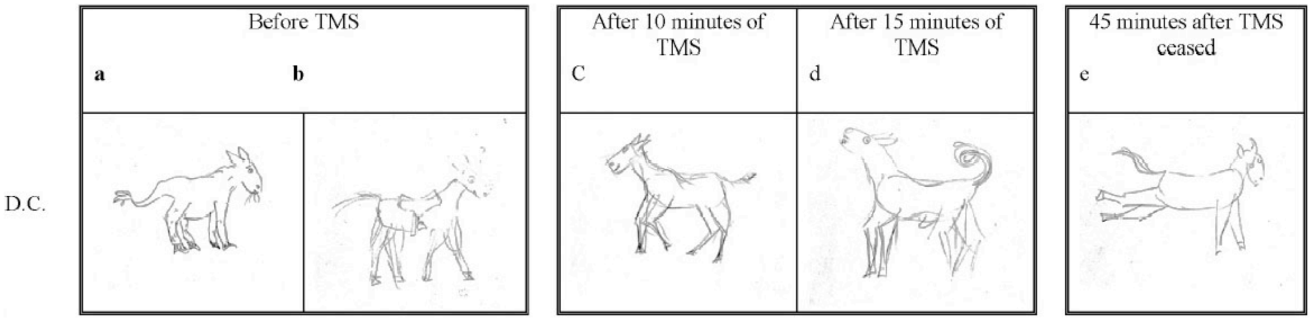


Figure 2. Effect of transcranial magnetic stimulation (TMS) on drawing a horse from memory by participant D.C. a, b, practice session before TMS; c, during; d, immediateely after and e, 45 minutes after TMS ceased. Participant D.C. also displayed enhanced proofreading during and after TMS.

During and after real stimulation, R.Y. changed his convention for drawing faces. In his placebo stimulation session (figure 3, upper drawings), the week prior to the real test, and in the drawings completed before real stimulation (figure 3, lower drawings f and g) a distinct schema is present in the drawings of R.Y. However, during and after *real* stimulation, this style changed and R.Y. became preoccupied by the details of eyes (figure 3, lower drawings h, i and j). These drawings were executed in one minute by R.Y. after viewing the corresponding image of figure 4 for 30 seconds.

Of all the participants, a change in drawing style following placebo stimulation was only observed on one occasion and in this single case, the style change did not persist in the drawings that followed.

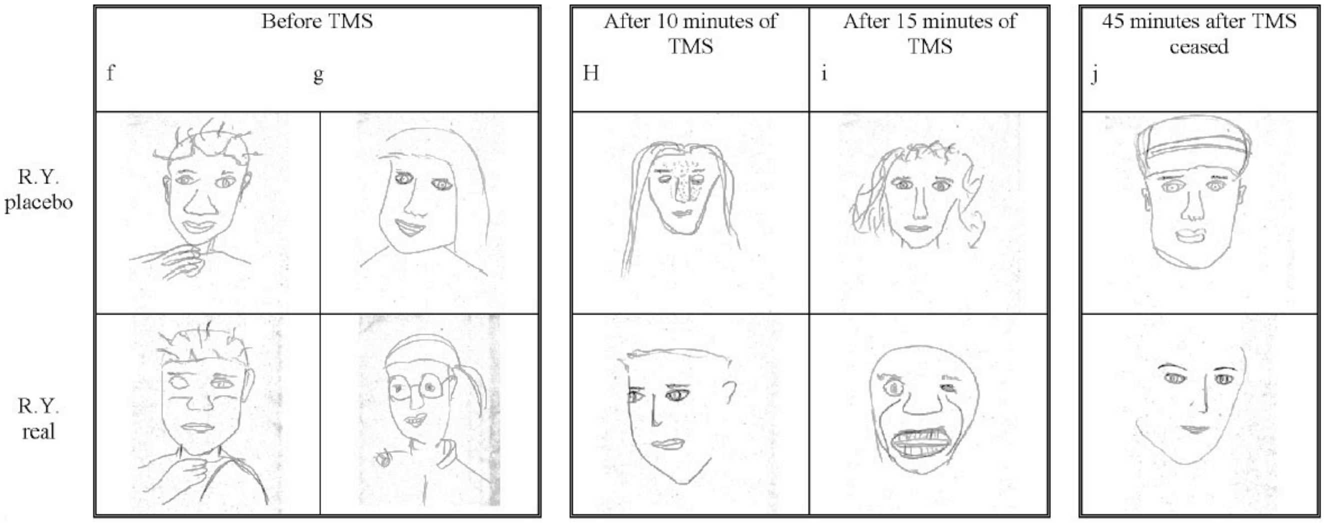


Figure 3. Effect of transcranial magnetic stimulation (TMS) on drawing a face remembered from an image shown previously, by participant R.Y., f, g, practice session before TMS; h, during; i, immediately after and j, 45 minutes after placebo/placebo stimulation (top row) and real (bottom row) stimulation. Participant R.Y. also displayed enhanced proofreading during and after TMS.

Figure 4. Participant R.Y. was shown each of these images for 30 seconds before being given one minute to draw them

3.2. Reports of Altered States of Perception

Three of the four ‘facilitated’ participants (N.R., D.C., and R.Y.) experienced altered psychological states after stimulation (see table 1). For example, N.R. said he was more “alert” and “conscious of detail” and that we had “taught him how to draw dogs.” He wished he had been asked to “write an essay”, something he previously disliked, because when stimulated he became acutely aware of detail in his surrounds. Furthermore, the drawings of these three participants had not reverted to their original convention 45 minutes after stimulation had ceased. It is possible that the altered psychological states persisted beyond this time frame or that the newly acquired schema was preserved once learnt under magnetic stimulation.

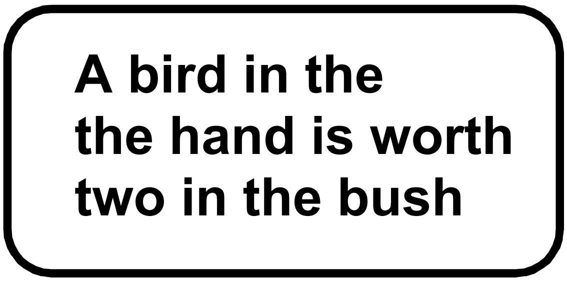
Table 1: Summary of the four participants whose skills were altered by magnetic stimulation

Change in drawing style	Enhanced proofreading ability	Altered psychological experience
D.C.	D.C.	D.C.
R.Y.	R.Y.	R.Y.
A.J.		†
N.R.		N.R.

† A.J. did not give a subjective report

3.3. Proofreading

It has been suggested that savant-like drawing skills are a product of a literal mind, one with access to unprocessed information(20,21). To provide a more objective measure of literalness, the participants underwent a quantitative test for proofreading.



A bird in the
the hand is worth
two in the bush

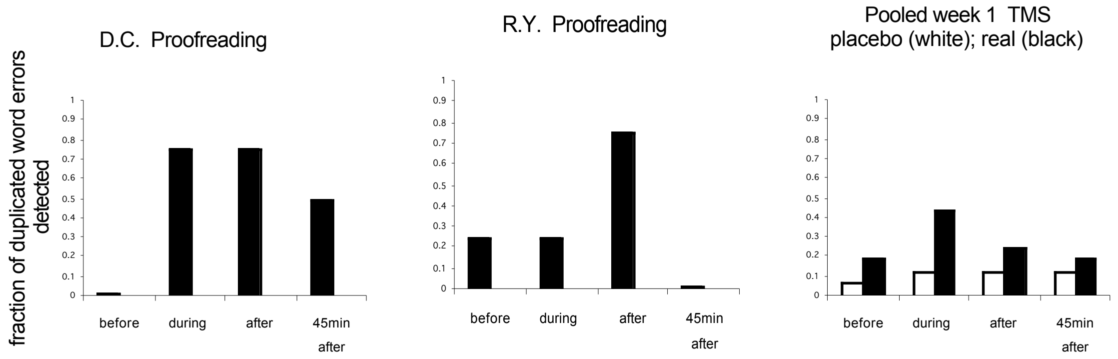
Figure 5. Example of the proofreading test. Sample of a proverb presented to participants. Without stimulation, participants almost always missed the duplicated ‘the’ in the sentence.

In this test, the participant was presented with a series of 10 proverbs on a computer screen. Each proverb was presented on the screen for two seconds, during which time the participant read the proverb aloud. Two of the proverbs in the set contained an error where a word was duplicated (figure 5). Following the proverbs a paragraph appeared on the screen, which again the participant read aloud. The paragraph also contained two duplicated word errors as well as some spelling and grammatical errors. Participants were instructed to read all the text *including* the errors, i.e. to identify any errors they saw in the text.

This test was designed to demonstrate that, unlike autistic savants(5,22), our propensity to impose meaning and concept blocks our awareness for the detail making up the concept(20,21). Two participants (D.C. and R.Y.) displayed a noticeable improvement in their ability to recognise duplicated words in text following stimulation (figure 6 a, b). They did comparatively well during and or immediately after stimulation and comparatively poorly both before and 45 minutes after. *Importantly, these are the same two participants who displayed pronounced style changes in their drawings during and after real stimulation (see summary table 1) but not after placebo stimulation.* As with the drawing task, no improved proofreading ability was associated with placebo stimulation.

None of the participants improved at proofreading with placebo stimulation unless it was administered a week after the real stimulation when the types of errors had become familiar. When improvements were observed with the placebo stimulation they were continuous, and did not decrease in the test carried out 45 minutes after stimulation, as was the case in the real test. This suggests that any improvements seen with placebo stimulation were merely a consequence of learning.

These proofreading results provide non-subjective evidence of the ability to switch on a savant-like skill by turning off part of the brain in healthy individuals. *We emphasise that, without stimulation, participants almost always missed errors such as the repeated 'the' in Figure 5, even after many exposures.* This fact is illustrated by the poor performance of all participants who received placebo stimulation in week one (figure 6c).



a b c

Figure 6. Duplicate word errors (like those in figure 5) detected in the proofreading task before, during, immediately after and 45 minutes after magnetic stimulation (TMS) in two participants (a, D.C. and b, R.Y.). c, Average number of duplicate word errors detected by all participants (who received both real and placebo TMS) during their first session (white: placebo TMS group; black: real TMS group).

4. Discussion

The concept behind this investigation is that it is difficult for us to access "lower" level neural information. We are aware of object "labels", not the attributes used by our brains to formulate the labels. Such attributes are normally suppressed from conscious awareness(18,20). For example, we are not consciously aware of the subtle shading across a spherical object which our brain uses to derive its shape and label it "sphere"; otherwise, we would be better at drawing natural scenes without training(18,19). But, a rare form of brain impairment enables savants to have access to such information(20,21). Our findings suggest that low frequency TMS mimics this brain impairment by shutting down part of the left fronto-temporal lobe. The possible (disinhibiting) neural mechanisms that underlie TMS induced access to information that is normally inaccessible are explored in a forthcoming paper.

Apart from brain impairment and magnetic stimulation, savant-like skills might also be made accessible by altered states of perception(20) or by EEG-assisted feedback(1). Sacks(17) provides support for the former view. He produced camera-like precise drawings only when under the influence of amphetamines. Early (savant-like) cave art has been attributed to mescaline induced perceptual states(8). Interestingly, three of our four positive responders reported altered psychological states after magnetic stimulation (Table 1).

5. Conclusion

In conclusion, low frequency TMS of the left fronto-temporal lobe did not lead to a systematic improvement of artistic performance. But, it did cause major changes in the scheme or convention of drawings for four of eleven participants, two of whom significantly improved at proofreading (see table 1). We emphasise that these changes are due to the inhibiting influence (6,14) of low frequency TMS. They are due to turning off part of the brain, not exciting it.

There are many variables in the application of TMS which could reduce the efficacy of the magnetic pulses, but these difficulties only serve to increase the significance of our positive findings. If the method of stimulation could be made more precise, all participants might have been influenced equally. The analogy is that of an effective drug which cannot be reliably delivered to the right location. However, the intent of our study is not to devise a clinical application, but rather to provide empirical evidence for the hypothesis(2,20) that savant-like skills can be facilitated in a healthy individual by suppressing part of the brain with TMS.

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